CORAL FAUNA OF TAIPING ISLAND (ITU ABA ISLAND) IN THE SPRATLYS OF THE SOUTH CHINA SEA

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ABSTRACT

The coral fauna of the Taiping Island (Itu Aba Island) in the Spratlys of the South China Sea was surveyed on April 19-23, 1994. A total of 163 species of scleractinians in 15 families and 56 genera; 15 species of alcyonaceans in three families and five genera; and six species of gorgonaceans in four families and five genera were recorded. The coral communities of the Taiping Island were dominated by scleractinian corals with high species diversity and coral cover found on the lower reef flat at depths between 1 and 3 m. Alcyonaceans and gorgonaceans are mainly distributed on the reef slopes at depths below 15 m. Wide reef flats and reef terraces exist on the east and west sides of the island indicating that the reef development is better in these areas. Species diversity of coral communities was the highest on the east side and the lowest on the west side of the island. The depauperate coral fauna on the west side is possibly related to the strong SW monsoon during summer and autumn. In comparison with other tropical coral reefs, species diversity and abundance of coral communities of Taiping Island are relatively low. Dead coral skeletons and debris were widely spread on the reefs below 3 m deep and only small colonies were found. These facts indicate that coral communities of Taiping Island may have been heavily damaged by natural catastrophes or artificial destruction during the last decade. The possible destruction forces are typhoon disturbances and sea warming events.

INTRODUCTION

The South China Sea, situated between the Indian and Pacific Oceans, has an historical importance in politics, economics, military affairs and transportation (Gomez, 1994). As the South China Sea is surrounded by continental Asia and many islands, it is generally recognized as the major marginal sea in Asia. Major islands in the South China Sea such as Tungsha Island (Pratas Island), Xisha Islands (Paracel Shoals) and Nansha Islands (Spratly Islands) are reef islands. Most reef islands are atolls or emergent islands, which are mainly composed of coral debris and sand. The emergent islands constitute only a small portion of the reefs; the major parts are underwater reefs, shoals and banks.

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The Spratly Islands, consisting of some 600 coral reefs and associated structures scattered across an area north of Sabah and southern Palawan stretching for more than 500 km, are a group of atolls, islets, and sea mounts in the South China Sea. The structures which protrude above the sea surface at high tide include at least 26 islands and seven exposed rocks (McManus, 1992). Taiping Island, or Itu Aba Island, is one of the major islands in the Spratly Islands.

The Indo-Pacific region, which includes the Spratlys, is characterized by a high diversity of marine organisms. Among reef building corals, for example, the region in which the Spratlys reside includes at least 70 genera (Veron, 1986, 1993). In the coral reef ecosystem alone, more than 400 species of corals (Veron and Hodgson, 1989), 1500 species of reef fishes and 200 species of algae are found in this area (McManus, 1994). The exact number of all marine species in the South China Sea is difficult to estimate given the inadequate state of taxonomy, but the total number of species to be found at all depths in the Spratlys certainly ranges to the tens of thousands (McManus, 1992).

The marine ecosystem of the South China Sea can be assumed to be dependent on the Spratlys, at varying levels, for sources of larvae of renewable resources. Due to prevailing monsoonal currents, the Spratly reefs may serve as sources of larvae that could recruit to the disturbed coral reefs in the South China Sea (McManus, 1994). The semi-enclosed nature of the South China Sea and hydrodynamic patterns prevailing in the area could explain this linkage of coastal ecosystems in terms of nutrient level and fauna. It is very likely that the Spratly Islands and similar groups of uninhabited reefs serve as a mechanism for stabilizing the supply of young fish and invertebrates to these areas. This becomes increasingly important wherein coastal populations of adult fish decline, as appears to be the case in many coastal reefs of the Philippines and elsewhere. The dispersal of larvae from the Spratlys possibly contribute to the coral reef fishery in the region. The contribution of coral reef fishery to the national fish production of countries bordering the South China Sea varies between 5-60% (McManus, 1994). Thus, the Spratlys could be considered as a “saving bank” where commercially important fish and invertebrates are saved from overharvest and supply a constant flow of larvae to areas of depletion.

Coral reefs are widely distributed in shallow water areas in the South China Sea. The high spatial heterogeneity and productivity of coral reefs provide not only various habitats for marine organisms but also feeding and nursery grounds for fishery resources such as fish, shells, crustaceans and cephalopods. Flourishing coral reefs also constitute beautiful underwater scenery that are valuable resources for the development of touristic industry. As corals play a key role in marine ecosystems of the South China Sea, a better understanding of the coral fauna in this area is necessary for conservation and management of the marine resources in the future.

Several scientific expeditions in the South China Sea over the last 50 years have provided oceanographic information and taxonomic listing of marine organisms, mainly fishes. Although corals are widely distributed in the South China Sea, the coral fauna of this area is poorly documented because of its remoteness and difficulty of access. Bassett-Smith (1890) first described corals from Tizard Bank. Ma (1937) studied the growth rates of scleractinian corals from Tungsha Island (Pratas Island). In recent years, a few expeditions have been conducted to investigate the fauna and flora of the South China Sea (Yang et al., 1975; Zou, 1978a, b; Fang et al., 1990). These studies have provided valuable information for a preliminary understanding of the coral fauna of this area. However, in comparison with the vast area of the South China Sea, these studies have only covered a very restricted area. Studies on the coral fauna in other areas are thus necessary.

We sought to provide baseline information for resource conservation and exploitation of Taiping Island (or Itu Aba Island). The objectives of this work were to survey and to describe the distribution of coral reefs and reef topography, to provide an inventory of coral species and their estimated relative abundance, and to identify special coral biotopes.

STUDY SITE AND METHOD

Seven sites around Taiping Island (Fig. 1) were surveyed on April 19-23, 1994. Taiping Island (10°23'N, 114°22'E), located on the northwest side of Tizard Bank, is one of the major islands on the west side of the Spratly Islands (Nan-sha Islands). The island, with an area of 0.49 km^2, is about 1300 m long and 350 m wide (Fig. 3). The climate is tropical oceanic. The average water temperature is about 28-29°C. The island is influenced by seasonal monsoons. The northeast monsoon blows from October to March, the southwest monsoon from May to October. The current flows southeast during the former and east or north during the latter (UNEP/IUCN, 1988).

Coral reefs were surveyed by snorkeling and scuba diving. Reef topography, coral species, community types and estimated coral cover were recorded. The relative abundance of each coral species was estimated according to the number of colonies encountered during each survey as common with more than 50 colonies, occasional with about 10-50 colonies, or rare with less than 10 colonies. Underwater camera and video were used to record photographs of coral colonies and reef topography. Coral species were identified in the field. Whenever confronted with an uncertain species identification, a piece of coral skeleton was detached and brought to the laboratory for further identification. The identification of species was based on Veron and Pichon (1980, 1982), Veron and Wallace (1984), Veron et al. (1977), Veron (1986), Dai (1989), Hoeksema and Dai (1991), and Dai and Lin (1992).

RESULTS AND DISCUSSION

Description of Reef Topography and Coral Community

Site A is located on the south side of the island. The substrate of the upper reef flat at 1-2 m depth is covered with sand and seagrasses. On the lower reef flat at 2-4 m depth, there are abundant massive and stoutly branching colonies of *Porites*, *Acropora* and *Pocillopora* spp. Below the reef flat at depths between 4 and 15 m, there is a steep slope; only a few foliaceous *Montipora* and branching *Acropora* colonies were found on the surface of the slope. At depths between 15 and 21 m, it is a reef terrace. The substrate is flat and composed of coral debris with some ridges and grooves (Fig. 2a). The coral cover is less than 5%; only a few small colonies are scattered on the substrate. The species diversity was quite high, more than 67 species were recorded. The most abundant species at this site is the octocorallian, *Isis* sp. (bamboo coral). They can form large colonies of 1 m long and in dense assemblages at some locations. Scleractinians found here are mainly species of *Montipora, Favia, Favites, Goniastrea* and *Cyphastrea*. They typically exist as small colonies with a diameter less than 10 cm. The widespread coral debris covering the substrate was mainly *Acropora* and *Pocillopora* skeletons indicating that there were flourishing branching coral communities in the past. The scarcity of coral species and scattered small colonies indicate that the community might have been destroyed recently and that recovery is slow.

Site B is located on the southeast of the island. Reef topography is similar to Site A. There is a reef flat about 50 m wide at depths between 0 and 4 m. Living coral cover on the reef flat exceeds 50%, but a trend of decrease toward the west is evident. Scleractinian corals of about 120 species were found. Species commonly occurring on the reef flat were stoutly branched colonies of *Pocillopora damicornis, P. verrucosa, P. eydouxi, Acropora monticulosa* and *A. gemmifera* (Fig. 4). Colonies of *A. digitifera, A, palmera, Favia speciosa, Leptoria phrygia, Platygyra lamellina* and the hydrocoral, *Millepora platyphylla* were also commonly found on the reef flat. These species generally form large colonies with diameters greater than 1 m. Corals existing on the flat are mainly massive, encrusting and stoutly branched forms. The colony morphology of corals of this area indicates that the reef flat is exposed to strong wave action. Below the reef flat on the seaward side between 5 and 18 m is a steep slope on which coral cover was less than 5%; only a few coral colonies were found to grow on the surface of the slope. A few solitary corals of *Fungia* spp. and several large colonies of the blue coral, *Heliopora coerulea*, were found on the sandy grooves. Below 18 m the bottom is sandy and no coral was found.

Site C is situated on the west of the island. It is characterized by a wide reef flat that extends westward to over 500 m from shore with depths about 3-8 m (Fig. 2b). On the surface of the flat, there are low reef ridges alternating with shallow grooves running in the NE-SW direction. Currents of this area are generally strong especially during flood and ebb tides. This area is also exposed to strong waves during the summer monsoon. The substrate on the upper reef flat was characterized by a dense seagrass bed. The lower reef flat was covered with dead coral skeletons; some of them were clearly identifiable based on skeletal features. Few small colonies were found and the coral cover was less than 2%. These phenomena indicate that the coral communities might have been destroyed during the past decade. Some small soft coral colonies such as *Sarcophyton* spp. and *Lobophytum* spp. were scattered on the substrate (Fig. 5); few attained a diameter of 50 cm.

Site D is located on the northwest side of the island. The reef flat has a width about 100 m and stretches from 1 to 6 m deep (Fig. 2c). Coral communities on the reef flat can be divided into two zones. In the upper zone between 1 and 3 m deep, coral cover is higher than 50%. Species common in this zone are *Favia, Favites, Goniastrea, Coeloseris mayeri* and *Pavona* spp. Some large colonies with diameters greater than 1 m were found. In the lower zone between 3 and 6 m deep, coral diversity is low and coral cover is less than 10%. The reef surface is covered with dead coral skeletons and algae. Below 6 m, there is a steep drop-off, descending at a nearly perpendicular angle to a depth about 60-80 m. On the wall of this drop-off, there are colonies of *Dendronephthya* spp., *Junceella fragilis* and *Isis* sp. Scleractinians were rare; only few small colonies of foliaceous corals were found to grow on the slope. The coral cover is less than 5%. However, sponges, bryozoans and other sessile invertebrates are abundant.

Site E is situated on the northeast side of the island. Reef topography and coral fauna of this site are similar to those of Site D. On the upper zone of the reef flat, the coral cover was higher than 50% and approximately 100 scleractinian species were found. Among the most abundant species are *Pocillopora verrucosa, P. eydouxi, Acropora digitifera, Heliopora coerulea*, and *Millepora platyphylla* (Fig. 6). Species of *Montipora, Porites, Favia, Favites* and *Goniastrea* are also common in this zone; most of them are massive, encrusting or stoutly branched forms, with colony sizes often less than 30 cm in diameter. At the lower zone between 3 and 6 m deep, the substrate is covered mainly by dead coral skeletons and green algae, *Caulerpa* spp. The coral cover is less than 5% in this zone. There is a steep drop-off below 6 m; many large gorgonian and antipatharian colonies were found overhanging on the slope. Sponges, bryozoans, crinoids and other groups of marine invertebrates are abundant, which comprise a rich benthic fauna and colorful scenery (Fig. 7). Below 35 m the bottom is sandy and no coral was found.

Site F is located on the east side of the island. The reef flat is wider in the north where it extends seaward to approximately 500 m from shore but becomes narrower to the south (Fig. 2d). Dense coral cover (>50%) and high species diversity were found on the upper part of the reef flat at depths between 1 and 3 m. More than 100 scleractinian species were recorded, most of them were small colonies. Species commonly present in this area are *Pocillopora damicornis, P. verrucosa, Acropora digitifera, Cyphastrea chalcidicum* and *Favites abdita*. Coral cover and species diversity are low on the lower part of the reef flat. Less than 5% of the substrate was covered by corals and only few small colonies were found. Below 6 m there is a steep drop-off that extends to about 30 m and reaches the sandy bottom. The most peculiar organisms on the surface of the slope are many colorful soft corals, *Dendronephthya* spp. hanging on the wall. Other corals are rare and scattered. Below 35 m the bottom is sandy and no corals were found.

Site G is located on a reef ridge on the southeast of the island. The reef ridge is separated from the island by a trough approximately 20 m deep (Fig. 2e). The surface of the ridge is smooth and about 7 m deep. More than 70 species of scleractinian corals were found on the top of the ridge, mainly species of *Acropora, Favia, Favites, Goniastrea,* and *Fungia*. The coral cover is about 30-40%. Many colonies of solitary corals such as *Fungia cyclolites, F. costulata, F. tenuis, F. fungites, F. scutaria* and *Herpolitha limax* were found on the sandy grooves. The edge of the reef ridge is about 8 m deep. Below 8 m there is a steep slope down to approximately 37 m. There are several *Tubastraea micranthus* colonies growing on the upper part of the slope. The lower part of the slope between 20 and 37 m deep is covered by thick patches of *Dendronephthya* colonies (Fig. 8). These colorful soft corals, when fully extended, form a gorgeous underwater "flower wall". The slope reaches the sandy bottom at 37 m.

Coral Fauna

A total of 163 species in 15 families and 56 genera of scleractinians; 15 species in three families and five genera of alcyonaceans; and six species in four families and five genera of gorgonaceans were recorded during this survey (Table 1). The results showed that coral communities of the Taiping Island are dominated by scleractinian corals with high species diversity and abundant coral cover found on the reef flat between 1 and 3 m deep. Alcyonaceans and gorgonaceans are relatively rare and their distributions are limited to reef slopes at depths below 15 m. Although the coral fauna varied slightly among the surveyed sites, species compositions of the coral communities are similar and can be regarded as typical of tropical reef communities. The abundance of small coral colonies indicates that coral communities are in their early stages of succession (Grigg, 1983). As early succession communities generally have high species diversity (Connell, 1978), this conditions may also relate to the high diversity of coral communities at Taiping Island.

In comparison with the known coral fauna of other reefs in the South China Sea, the number of scleractinian species recorded during this study exceeds those of Tungsha Island (Pratas Island, 101 species; Dai et al., 1995) and Xisha Islands (Paracel Shoals, 127 species; Zou and Chen, 1983). In general, the species composition of the coral fauna among these islands is similar. Biogeographically, these coral fauna belong to the Indo-Pacific province. Because Taiping Island is situated at a lower latitude and closer to the area of highest coral diversity, it is natural that its coral fauna is more diverse than those of other reefs in the South China Sea. According to the biogeographical location of Taiping Island, this island is expected to have more than 70 genera and 400 species of scleractinians (Veron, 1993). However, during our brief survey to the island, only 51 genera and 163 species were recorded (Table 1). Further intensive surveys of adjacent islands may reveal more species.

The coral reef of Taiping Island is a typical oceanic reef. It has a wide, shallow reef flat and a steep drop-off on the edge of the flat. The reef flat is a site of intensive coral calcification that forms the reef framework. The substructure of this region is invariably composed of large, massive, interlocking colonies of hermatypic corals cemented by calcareous algae. The drop-off borders the reef framework and generally descends to depths below 30 or 60 m. At the base of the drop-off there are abundant coral debris and accumulation of sediment. These facts indicate that physical and biological destruction of the reefs is relatively high and debris produced through these processes are transported to a deeper zone at which accumulation occurs.

The development of reefs on the southwest and northeast sides of Taiping Island is better than that of other areas. On both sides there are wide reef flats extending beyond 500 m from shore which basically conform to the shape of the island. Such a pattern of reef development is likely related to the water flow of the reef as both sides are located in the path of tidal current entering and leaving Tizard Bank. Reef growth is usually better where there is strong water flow (Stoddart, 1969; Goreau and Goreau, 1973) because this flow brings food and raw materials at the same time that it removes sediments and waste products. In terms of species diversity, coral communities on the east, southeast and northeast sides of the island are higher than in other areas. The depauperate coral fauna on the west and southwest sides are possibly related to the strong SW monsoon during summer and fall. Zou et al. (1978) reported that coral communities of Xisha Islands (Paracel Shoals) were well developed on the northeast side and poorly developed on the southwest side of the islands and that such distribution patterns are likely related to local flow patterns. Due to the influence of the prevailing SW monsoon during summer, such distribution patterns of coral communities are likely common in the South China Sea.

The tropical reef environment of Taiping Island implies that its coral fauna is rich and the reef is highly developed. However, in comparison with other tropical Indo-Pacific coral reefs, the species diversity and abundance of coral communities at Taiping Island are relatively low. Dead coral skeletons were widely spread on the reef surface below 3 m and only small coral colonies were found. These facts indicate that the coral communities of Taiping Island have suffered severe damage during the last decade. The cause of such extensive coral death is uncertain. Many natural and anthropogenic stresses on coral reefs have been reported (see reviews by Brown and Howard, 1985; Grigg and Dollar, 1990). According to the current status of the reef environment, the possible disturbances are likely include artificial destructions, pollution, storms, predation of *Acanthaster planci*, and El Niño events.

Artificial destructions including blast fishing and underwater bombardment may have caused heavy destruction in certain areas. The presence of idle troops at Taiping Island is also of concern because they may engage in environmental damaging activities such as shooting and fishing with explosives. Substantial damage may also come from occasional parties of blast fishers and coral-smashing muroami fishers from the Philippines and Vietnam (McManus, 1992).

The possibility of oil pollution is also of concern because the Spratlys lie near to major shipping lines for oil and nuclear waste. Oil and nuclear waste could be released in the event of a tanker accident in these reef-studded waters (McManus, 1992). However, we found no substantial record or evidence of these pollutants.

The tropical position of Taiping Island places it within the area of frequent typhoon disturbances. The typhoon-generated waves and storm surges may erode reef crest corals and sediments down to about 20 m depth (Stoddart, 1985; Scoffin, 1993). The recognition of past storm disturbances may rely on several features such as the deposits of coral debris, the assemblages of corals and other reef biota, the reef framework structure, and the existence of reef flat storm deposits (Stoddart, 1971; Scoffin, 1993). During this survey, widespread coral debris were found to accumulate as talus at the foot of the fore-reef slope, on submarine terraces and in grooves on the reef front. In addition, on the shallow reef flat there are mainly massive, encrusting or stout branching corals that are basically wave-resistant forms. These facts indicate that typhoon disturbances are possibly the major destructive forces that have caused severe damage to the coral communities of Taiping Island.

The population outbreak of the crown-of-thorn starfish, *Acanthaster planci,* has been recognized as the most potent biotic disturbance affecting coral communities on many Indo-Pacific reefs (Endean and Cameron, 1990). However, on reefs where marked destruction of hard-coral cover was not apparent, *A. planci* was either not observed or found at very low populations densities. Since we did not find any individual of *A. planci* during this survey, it was unlikely that the crown-of-thorn starfish was the major destructive force to the coral communities of Taiping Island.

Global sea warming associated with El Niño events has caused widespread coral bleaching in the Caribbean and the Pacific (Glynn, 1984, 1988; Williams and Bunkly-Williams, 1990; Gleason, 1993). The ecological consequences of bleaching events include widespread mortality with resultant decreases in coral cover, changes in species composition, reduced growth rates and reproductive output of corals (Szmant and Gassman, 1990; Gleason, 1993). Mortality rates in bleaching events have ranged from zero (Hoeksema, 1991) to very severe (50-98%) as on the eastern Pacific during the 1982-83 El Niño event (Glynn, 1988). This severe event also had other associated secondary disturbances following coral mortality such as a subsequent increase in number of grazers and bioerosion rates (Glynn, 1988). Whether the widespread mortality of corals at Taiping Island is related to the El Niño-Southern Oscillation (ENSO) events need to be studied. Analysis of the environmental record in coral skeletons and marine environmental data are thus needed to answer this question.

In conclusion, the coral fauna of Taiping Island is dominated by scleractinian corals, distributed mainly on the shallow reef flat at depths of 1-3 m on the east, south and north sides of the island at which flourishing coral communities were found. Few gorgonaceans and alcyonacean species were found mainly on deeper reef slopes. Coral cover and species diversity of Taiping Island are relatively low in comparison with other tropical Pacific coral reefs indicating that the coral communities of Taiping Island may have been destroyed by artificial or natural disturbances. Since flourishing of coral communities and reef-building activities are the basis of sustained development of this island, we propose that reef conservation and protection are urgent and should be enforced immediately by reducing artificial destruction and pollution to the reefs. In addition, the changes of reef environment and biotic communities should be monitored. On a broader scale, the Spratly Reefs, including Taiping Island, are ecologically important, with abundant and relatively unexploited resources and where endangered species still abound. The Spratlys may also serve as a pool of larvae for fishes and other marine organisms that recruit to depleted fringing reefs and coastal habitats of the South China Sea. For these reasons, it is worthwhile to conserve the ecosystem and genetic diversity of the Spratlys by establishing a marine park in the Spratlys as proposed by McManus (1992).

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Table 1. Distribution and relative abundance of shallow water corals at seven study sites (A-F) of Taiping Island. Relative abundance, +: rare, ++: occasionally, +++: common.

species / Site	A	B	C	D	E	F	G
SUBCLASS ZOANTHARIA							
ORDER SCLERACTINIA							
Family ASTROCOENIIDAE							
Stylocoeniella armata		+	+		+	+	+
S. guentheri	+	+		+		+	
Family THAMNASTERIIDAE							
Psammocora profundacella	+	++	+	+	++	++	+
P. digitata		+	+		+		+
P. contigua		+	+	+	+	+	
Family SIDERASTREIDAE							
Pseudosiderastrea tayami					+	+	
Coscinarea columna	+	+		+			
C. exesa				+			
Famliy POCILLOPORIDAE							
Pocillopora damicornis		+++	+	++	++	+++	++
P. eydouxi	+	++			++	+	+
P. meandrina	+	+	+	+	+	+	
P. verrucosa	+	+++	+	++	+++	+++	++
P. woodjonesi				+			
Seriatopora caliendrum		+				+	
S. hystrix	+	+	+	+		+	+
Stylophora pistillata	+	+	+		+	+	
Palauastrea ramosa	+						
Family ACROPORIDAE							
Acropora humilis		++	+	+	+++	+	++
A. gemmifera		+++	+	+	+	+	+
A. monticulosa		+++		+++	+	+	
A. digitifera	++	+++	+	+	+++	+++	+
A. robusta		++		+	+		+
A. palmerae		++		+	+	+	+
A. nobilis		++		+	++	+	
A. grandis		+			+		
A. microphthalma		+	++		+	+	
A. aspera		+		+			
A. millepora					+		
A. tenuis		+			++		+
A. cytherea				+			
A. hyacinthus		+			+	+	
A. nana			+		+		
A. cerealis		+	+				
A. nasuta				+			

species / Site	A	B	C	D	E	F	G
A. valida	++	+		+	++		+
A. lutkeni				+		+	
A. divaricata					+	+	
A. florida		+					
A. sp 1					+		
A. sp 2						+	
Astreopora myriophthalma		+					
A. listeri			+				
A. gracilis	+	+	+	+	+	+	+
Montipora monasteriata	+	++	+	+	++	+	+
M. turgescens	+		+	+	+		+
M. undata	+	+	+		+	+	
M. verrucosa	+	++	+	+	++	++	+
M. danae		+					
M. foveolata			+				
M. venosa	+	++		+	+		
M. digitata		+	+				
M. grisea			+				
M. informis	+	+	+	++	+	+	
M. foliosa			+				+
M. aequituberculata			+	+	+		+
Family AGARICIIDAE							
Pavona clavus		+					
P. explanulata		++	+		++	+	
P. varians		+	++	++		+	
P. venosa	+	++	+	+	++	++	++
Gardineroseris planulata		+	+		+	+	
Leptoseris mycetoseroides			+		+	+	
L. explanata	+	+					
Coeloseris mayeri	+		+	+	+	+	
Pachyseris rugosa	++	++		++	++	+	++
P. speciosa	+	++		+	++	+	++
Family FUNGIIDAE							
Fungia (Cycloseris) cyclolites		++					++
F. (C.) fragilis						+	+
F. (C.) costulata				+	+	+	++
F. (C.) tenuis		+			+	+	++
F. (C.) vaughani		+				+	+
F. (Verrillofungia) repanda	+	+		+	+	+	+
F. (V.) concinna					+		
F. (Danafungia) horrida		+					
F. (D.) scuposa				+			+
F. (Fungia) fungites		++		+		+	++
F. (Wellsofungia) granulosa	+	+		+			
F. (Pleuractis) gravis	+	+	+	+		+	+
F. (P.) paumotensis		+					
F. (Lobactis) scutaria	+	+	+		+	++	+

species / Site	A	B	C	D	E	F	G
Ctenactis echinata	+	+				+	+
C. crassa					+		+
Herpolitha limax	+			+	+	+	+
Polyphyllia talpina				+	+		
Sandalolitha robusta	+	+		+		+	+
Heliofungia actiniformis				+			
Family PORITIDAE							
Alveopora verrilliana					+	+	
A. spongiosa					+		+
Goniopora minor					+	+	
G. columna					+		+
G. stuchburyi						+	+
Porites (Porites) solida		++	+	+	++	+	+
P. (P.) lichen	+	+	+				
P. (P.) lobata	+	++	+		++	++	+
P. (P.) lutea	+	++	+		++	+	+
P. (P.) cylindrica	+	+		+	+	+	
P. (P.) nigrescens	+	+			+	+	+
P. (P.) annae		+			+		
P. (Synaraea) rus		+			+	+	+
Family FAVIIDAE							
Cyphastrea chalcidicum	+	+++		+	++	+++	++
C. microphthalma			+	+	+	+	+
C. serailia	+	++	+	+	++	+	
Caulastrea furcata		+				+	
Diploastrea heliopora	+	+		+		+	
Echinopora lamellosa	+	+	+		+	+	+
E. gemmacea				+			
Favia favus		++	+	+	++	++	+
F. pallida	+	++	+	++	++	+	+
F. rotumana		+					
F. speciosa	+	+++	+	+++	++	++	+
F. stelligera		+	+	+	+	+	
F. laxa			+	+			
Favites abdita	+	+++	+	++	++	+++	+
F. chinensis	+	+	+	+			
F. complanata			+				
F. flexuosa		++	+	+	++	+	+
F. russelli					+	+	+
F. pentagona	+	++	+	++		+	+
F. halicora		+					
Barabattoia amicorum				+		+	
Montastrea valenciennesi		+				+	
M. curta	+	++	+	+	++	++	+
M. magnistellata		+			+	+	
Goniastrea edwardsi	+	+	+			+	+
G. aspera	+	+					

species / Site	A	B	C	D	E	F	G
G. pectinata		++			++	+	+
G. retiformis		++	+	+	+	+	
Leptoria phrygia		+++	+	++	+	++	+
Platygyra pini		++		+	++	++	+
P. lamellina		+++	+	++	+		++
P. daedalea		++	+	+	++	+	+
P. sinensis		++	+		++	+	+
Plesiastrea versipora		+	+	+			
Leptastrea purpurea				+		+	+
L. pruinosa					+		
L. transversa	+	+			+		
Family OCULINIDAE							
Galaxea fascicularis	+	++	+	+	++	+	++
G. astreata	+	++	+	+	++	+	+
Family MERULINIDAE							
Merulina ampliata	+	+			+	+	+
Scapophyllia cylindrica		+			+		
Hydnophora exesa	+	++	+	+	++	++	++
H. microconos		++			++	++	+
Family PECTINIIDAE							
Echinophyllia aspera	+	+		+	+	+	+
E. echinata			+	+	+	+	
Oxypora lacera	+	+	+	+			
O. glabra		+					
Mycedium elephantotus		+					
Pectinia lactuca	+	+		+			
P. paeonia	+	++			++	+	+
Family MUSSIDAE							
Blastomussa merleti		+					
Cynarina lacrymalis	+						
Scolymia cf. vitiensis	+	+			+		
Acanthastrea echinata	+	++	+	+	+	+	+
A. hillai		+	+				
Lobophyllia hemprichii		+					
L. corymbosa	+	+			+		
Symphyllia recta		+		+		+	
S. radians		+		+			
S. agaricia	+	+					
Family CARYOPHYLLIIDAE							
Euphyllia (E.) glabrescens				+		+	
Family DENDROPHYLLIIDAE							
Turbinaria mesenterina				+			
T. reniformis	+	+					

species / Site	A	B	C	D	E	F	G
Tubastraea aurea				+			
T. micranthus				+		+	+
SUBCLASS OCTOCORALLIA							
ORDER STOLONIFERA							
Family TUBIPORIDAE							
Tubipora musica	+	++	+	+	++	+	+
ORDER COENOTHECALIA							
Family HELIOPORIDAE							
Heliopora coerulea	+	+++	++	+	+++	++	++
ORDER ALCYONARIA							
Family Alcyoniidae							
Sarcophyton ehrenbergi			+	+	+		
S. trocheliophorum			+			+	
S. glaucum			+				
S. sp.			+				
Lobophytum sarcophytoides			+	+			
L. mirabile			+	+	+		
Sinularia exilis			++	+	+	+	+
S. gibberosa			+	+	+		
S. numerosa			+	+			
S. sp. 1			+				
S. sp. 2				+			
Family Nephtheidae							
Dendronephthya sp. 1			+	+			++
D. sp. 2				+			+
D. sp. 3					+	+	+
Family Xeniidae							
Xenia sp.			+	+			
ORDER GORGONACEA							
Family Isididae							
Isis sp.	+++	+	+	+	+	+	+
Family Melithaeidae							
Melithaea ochracea				+	+	+	+
Family Subergorgidae							
Subergorgia sp.				++	+	+	++
S. sp.				+			+
Family Ellisellidae							
Ellisella robusta				+		+	
Junceella juncea				+	+	+	

species / Site	A	B	C	D	E	F	G
CLASS HYDROZOA							
ORDER MILLEPORINA							
Family MILLEPORIDAE							
Millepora platyphylla	+	+++	+	++	+++	+++	+
M. tenera	+		+			+++	+
M. intricata		+++				++	+
M. tuberosa				+			
Total No. of species	67	121	88	103	106	107	86

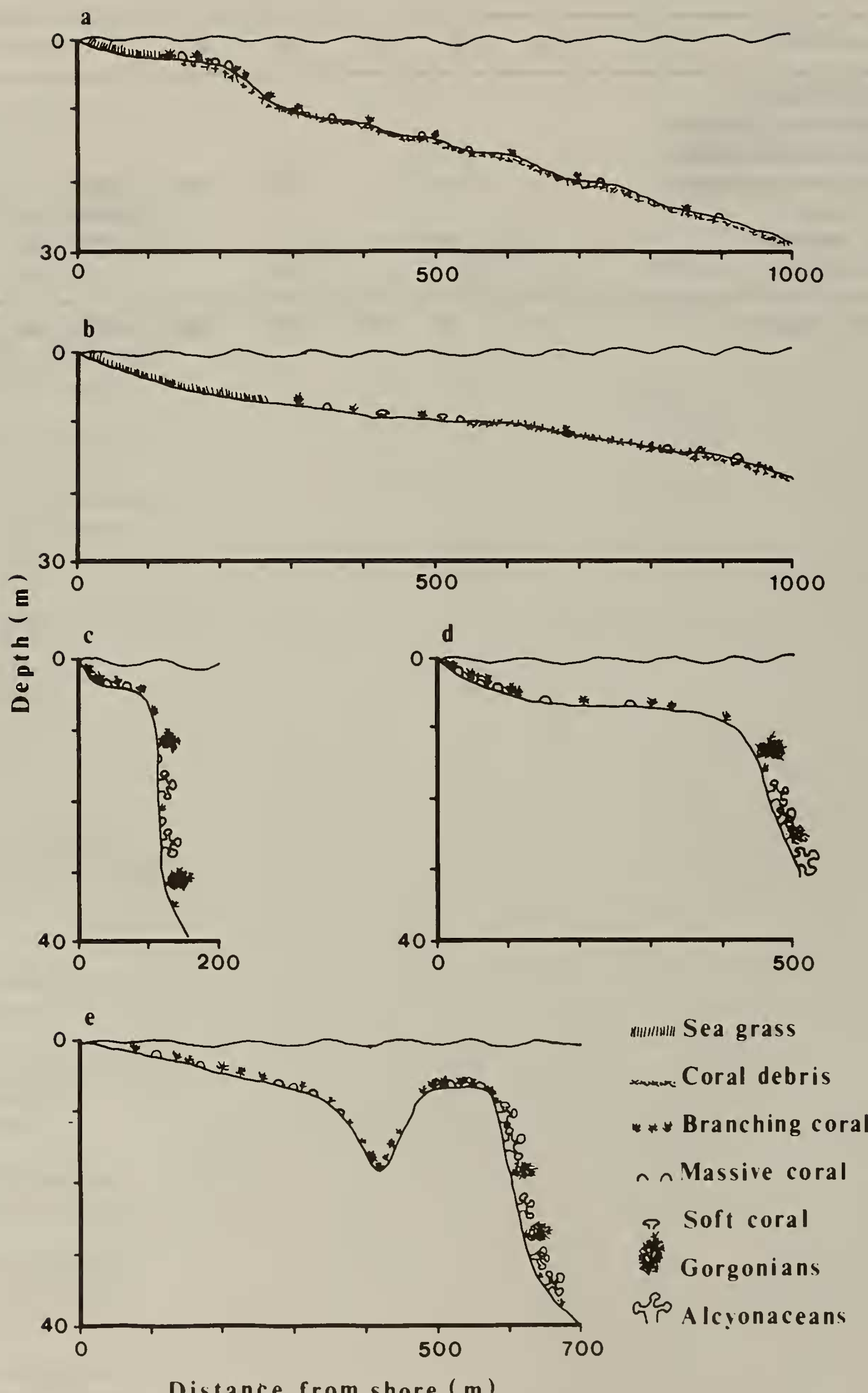

Fig. 2. Reef profiles and distribution of benthic organisms at the study sites.
a: Site A, b: Site C, c: Site D, d: Site F, e: Site G.

Fig. 3. Taiping Island, or Itu Aba Island, is a reef island about 1300 m long and 350 m wide.

Fig. 4. Coral community on the reef flat at Site B is dominated by stoutly branched colonies of *Acropora* spp.

Fig. 5. Some small soft coral colonies of *Sinularia* sp. scattered on the substrate at Site C.

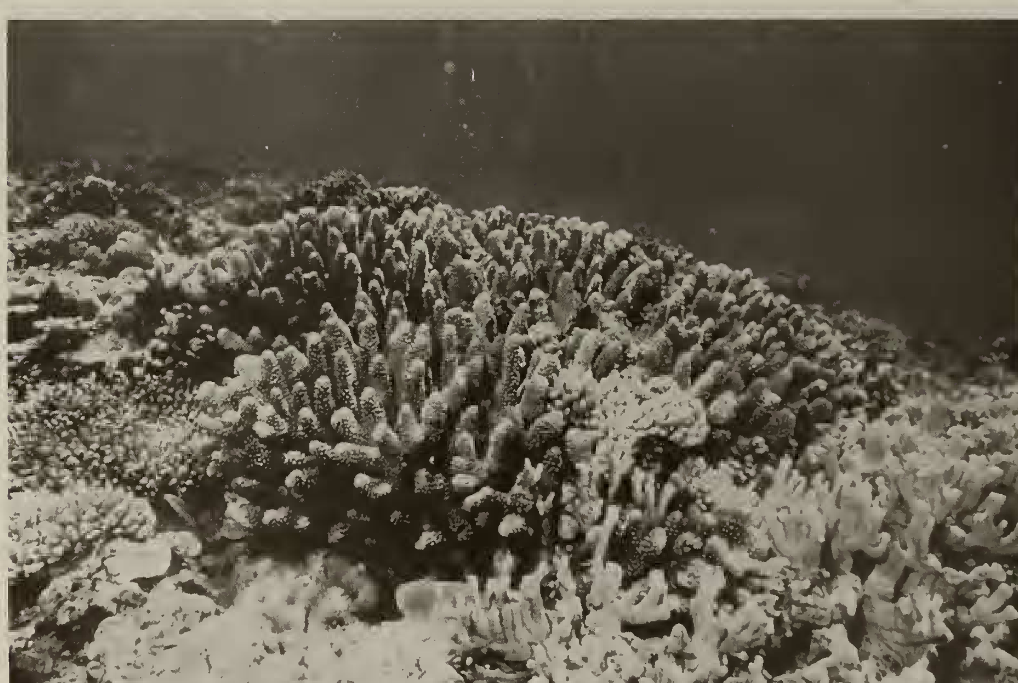

Fig. 6. Coral community on the reef flat at Site E is dominated by stoutly branched colonies such as *Pocillopora eydouxi*.

Fig. 7. Benthic community on the reef slope at Site E.

Fig. 8. Colonies of *Dendronephthya* sp. on the reef slope at Site G on the southeast of the island.